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Aortic Valve Replacement Using Continuous Suture Technique in Patients with Aortic Valve Disease

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Background: The continuous suture (CS) technique has several advantages as a method for simple, fast, and secure aortic valve replacement (AVR). We used a simple CS technique without the use of a pledget for AVR and evaluated the surgical outcomes. ***Materials and Methods:*** Between October 2007 and 2012, 123 patients with aortic valve disease underwent AVR alone (n=28) or with other concomitant cardiac procedures (n=95), such as mitral, tricuspid, or aortic surgery. The patients were divided into two groups: the interrupted suture (IS) group (n=47), in which the conventional IS technique was used, and the CS group (n=76), in which the simple CS technique was used. ***Results:*** There were two hospital deaths (1.6%), which were not related to the suture technique. There were no significant differences in cardiopulmonary bypass time or aortic cross-clamp time between the two groups for AVR alone or AVR with concomitant cardiac procedures. In the IS group, two patients had prosthetic endocarditis and one patient experienced significant perivalvular leak. These patients underwent reoperations. In the CS group, there were no complications related to the surgery. Postoperatively, the two groups had similar aortic valve gradients. ***Conclusion:*** The simple CS method is useful and secure for AVR in patients with aortic valve disease, and it may minimize surgical complications, as neither pledgets nor braided sutures are used.

Key words: 1. Aortic valve
2. Surgical procedure, operative
3. Outcome assessment
4. Suture techniques

INTRODUCTION

The continuous suture (CS) technique has been used as a simple, quick, and effective method for aortic valve replacement (AVR) [1,2]. We have used this technique without any specific modifications for AVR in 76 patients since October 2007. The CS technique may have some advantages over the conventional interrupted suture (IS) technique [1,2]. However, a recent paper with a long-term follow-up period reported that the CS group had a higher prevalence of perivalvular leak compared with the conventional IS group [3]. We thus evaluated the midterm results of the CS technique for AVR compared with those of the IS technique.

MATERIALS AND METHODS

1) Study population

From October 2007 to May 2012, a total of 123 patients

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Table 1. Preoperative data of the interrupted suture (n=47) and continuous suture (n=76) groups

Variable	Interrupted sutures	Continuous suture	p-value
Mean age (yr)	56.8±12.3	60.7±12.2	0.09
Male	24 (51.1)	41 (53.9)	0.85
Body surface area (m^2)	1.63±0.20	1.62±0.18	0.82
Pathology of aortic valve			0.13
Stenosis	8 (17)	25 (32.9)	0.06
Regurgitation	26 (55.3)	37 (48.7)	0.58
Mixed	13 (27.7)	14 (18.4)	0.27
Single aortic valve disease	14 (29.8)	14 (18.4)	0.19
Etiology of aortic valve disease			
Rheumatic	5 (10.6)	6 (7.9)	0.75
Degenerative	37 (78.7)	64 (84.2)	0.47
Endocarditis	5 (10.6)	5 (6.6)	0.50
Prosthetic failure	0 (0)	1 (1.3)	1.0
Redo aortic valve replacement	1 (2.1)	2 (2.6)	1.0
Follow-up period (mo)	41.9±14.6	22.5±10.8	<0.0001

Values are presented as mean±standard deviation or number (%).

Table 2. Concomitant procedures in the interrupted suture (n=33) and continuous suture (n=62) groups

Procedures	Interrupted sutures	Continuous suture	p-value
Isolate aortic valve replacement	14 (29.8)	14 (18.4)	0.19
Mitral valve surgery	14 (29.8)	29 (38.2)	0.44
Mitral valve replacement	11 (23.4)	17 (22.4)	1.0
Mitral valve repair	3 (6.4)	12 (15.8)	0.16
Tricuspid valve repair	9 (19.1)	18 (23.7)	0.66
Maze operation	8 (17.2)	18 (23.7)	0.50
Surgery for ascending aortic aneurysm	11 (23.4)	23 (30.3)	0.53
Reduction aortoplasty	2 (4.2)	18 (23.7)	0.005
Graft replacement	9 (19.1)	5 (6.6)	0.043

Values are presented as number (%).

underwent AVR alone or with concomitant cardiac procedures, such as mitral valve replacement, tricuspid valve repair, or maze operation for atrial fibrillation at our cardiac unit in Chonbuk National University Hospital. The patients were divided into two groups: an IS group, in which the interrupted horizontal mattress suture technique with buttressing pledgets in the ventricular side using 2/0 Dacron sutures was used to place the prosthetic valve in the aortic position; and a CS group, in which the CS technique using three to four 3/0 polypropylene sutures with 17-mm 1/2-circle needles was used to place the prosthetic valve.

In the IS group, there were 24 male (51.1%) and 23 female patients, and the mean patient age was 56.8±12.3 years (Table 1). Fourteen patients (29.8%) underwent isolated AVR, and 33 (70.2%) underwent AVR combined with mitral valve replacement, tricuspid annuloplasty, or maze operation for atrial fibrillation (Table 2).

In the CS group, there were 41 male (53.9%) and 35 female patients, and the mean patient age was 60.7±12.2 years (Table 1). Fourteen patients (18.4%) had isolated AVR, and 62 (81.6%) had AVR with concomitant cardiac procedures (Table 2). The etiology of aortic valve diseases was degenerative in the majority of cases in both groups, and the other etiologies were bacterial endocarditis (10 patients, 8.1%; 5 patients in each group), rheumatic valve disease (11 patients; 5 in the IS group and 6 in the CS group), and prosthetic failure due to organized thrombus (1 patient).

Most patients (113 patients, 91.2%) underwent AVR due to chronic valvular heart disease and 10 (8.1%) due to acute and subacute bacterial endocarditis. Preoperatively, transthoracic echocardiography was performed to evaluate the cardiac valvular lesion, heart structure, and function in detail. Surgery was performed by the same surgical team in all of the patients.

2) Surgical technique

Endotracheal general anesthesia and cardiopulmonary bypass (CPB) were instituted in a standard manner. For isolated AVR, a two-staged venous cannula was placed in the right atrium. For AVR with concomitant cardiac procedures, two venous cannulae were placed directly in the superior and inferior venae cavae. A 12-Fr or 14-Fr retrograde cardioplegic perfusion catheter was inserted into the coronary sinus through the right atrium in most of the patients. Moderate hypothermia (range, 28°C to 30°C) was achieved. After ventricular fibrillation was induced, a left ventricular vent catheter was inserted through the right superior pulmonary vein, and the aorta was then cross-clamped. Cold blood cardioplegia was initially infused into the aortic root or directly into the coronary ostia, and repeated retrograde cardioplegia was performed every 20 to 30 minutes. The diseased aortic valve was carefully excised by debridement, and the calcified

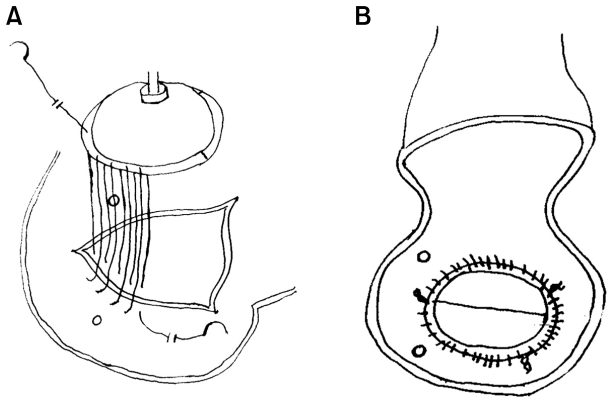

Fig. 1. (A) The first stitch was inserted into the prosthetic ring and then into the annular site 0.5 cm below the tip of the commissure between the right and left coronary cusps. The suture was continued counterclockwise to the left coronary annulus and completed before reaching the commissure of the left and noncoronary cusps. The second suture started at the site where the first stitch was completed and was continued counterclockwise in the noncoronary annulus to the membranous septum. The third suture started at the commissure between the right and left cusps and was continued clockwise along the right coronary annulus to the membranous septum. (B) By pulling the stitches one by one, the prosthetic valve was lowered to the annulus and the adjacent suture ends were tied.

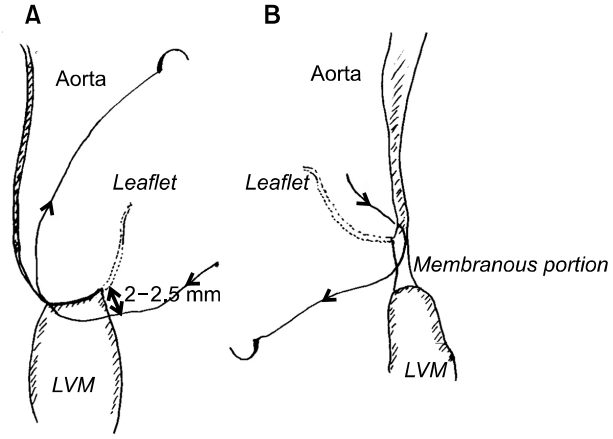

Fig. 2. (A) En-bloc annular stitching for the secure and comfortable placement of the prosthetic valve. In the left coronary annulus, the stitch was inserted deep into the ventricular side and out through the aortic sino-ventricular junction. (B) In the membranous septum between the right and non-coronary cusps, the stitch was placed deep into the membranous tissue of the membranous septum, leaving the muscular septum intact. LVM, lef ventricular muscle.

material in the aortic annulus was meticulously removed. Special care was taken to prevent debris from entering the coronary ostia and/or the left ventricular chamber. After an appropriate prosthetic valve was selected, it was placed using three to four 3/0 nonabsorbable monofilament polypropylene sutures with 1/2-circle 17-mm needles in the CS group. Three nadirs of the aortic annulus were marked with a blue pen to evenly divide the annular circumference into six parts. The prosthetic valve sewing ring was also marked in the same manner. The first stitch of the first suture material was placed in the prosthetic sewing ring and then in the ventricular side of the commissure between the left and right coronary cusps (Fig. 1A). The stitches were continued counterclockwise in the left coronary annulus, and were completed before reaching the commissure between the left and noncoronary cusps. In the left coronary annulus, the stitch needle was inserted in the ventricular side 2.0 to 2.5 mm below the annulus, and then out through the aortic sino-ventricular junction, catching sufficient ventricular muscle tissue adjacent to the annulus (Fig. 2A). The second suture was started at the point at which the first suture was completed. The stitches were continued counterclockwise along the noncoronary annulus to the membranous septum. The first suture was usually completed before reaching the commissure between the left and noncoronary cusps, but the second suture was frequently completed in the membranous septum. In the noncoronary annulus and membranous septum, the stitches were made to catch a sufficient amount of tissue of the strong aorto-mitral fibrous continuity and membranous septum, avoiding the muscular portion (Fig. 2B). This was an en-bloc annular stitch, not a simple annular stitch (Fig. 2). All stitches were made by forward sutures using the surgeon's right hand. In the left and non-coronary annuli, each stitch was made in the order of the first prosthetic valve sewing ring to the next aortic annulus. During suturing, the prosthesis was held firmly about 3 cm above the aortic annulus and traction on the suture helped identify the subsequent point of insertion on the aortic annulus [3]. The distance between the stitches was less than 3 mm (usually 2.0 to 2.5 mm) in order to securely seal the suture line. The prosthesis was loosely lowered to the aortic annulus by gently pulling the four ends of the suture. The third suture was started at the commissure between the right and left annuli, where the first suture started. The suture was con-

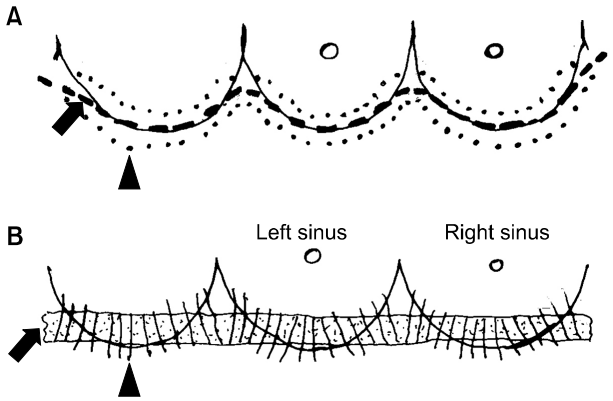

Fig. 3. (A) The plane of the stitches (arrowhead) for aortic valve replacement is curvilinear and resembles waves (arrow). (B) With the continuous suture technique, the prosthetic ring (arrow) was comfortably seated in the curvilinear suture line (arrowhead), and the annuli were buried in the stitch.

tinued clockwise toward the membranous septum along the right annulus. Each stitch was made in the order of the first aortic annulus to the next prosthetic sewing ring. After the right annular suture reached the membranous septum, the valve holder was removed. The sutures were carefully tightened stitch by stitch using a nerve hook, while confirming that there were no redundant suture loops beneath the valve. After the unimpeded opening and closing of the prosthetic valve was ensured, the adjacent ends of the suture were tied. The knots were fixed on the adjacent sinus with a 6-0 polypropylene figure-eight suture to prevent the disturbance of leaflet movement and the development of emboli just below the left coronary ostium. A prosthetic sewing ring was placed supra-annularly in the sinus nadir and infra-annularly in the commissures (Fig. 3). The aortotomy was closed with a double-layer suture of 4-0 polypropylene.

3) Postoperative follow-up

Echocardiographic studies were performed preoperatively, immediately after the operation, at the postoperative second week, at the postoperative sixth month, and then yearly thereafter. An angiotensin receptor blocker with or without a calcium-channel blocker was used to maintain the systolic blood pressure at less than 130 mmHg and to re-remodel the left ventricle. Anticoagulant therapy was given for at least 3 months and then discontinued in the patients who had undergone bioprosthetic valve replacement. For patients with a mechanical valve or atrial fibrillation, anticoagulation was continued.

Table 3. Cross-clamp times and duration of cardiopulmonary bypass in the interrupted suture (n=47) and continuous suture (n=76) groups

Variable	Interrupted suture	Continuous suture	p-value
Duration of cardiopulmonary bypass			
All procedures (min)	228.9±83.5	224.9±71.7	0.78
Isolated procedures (min)	182.2±58.5	150.6±34.6	0.09
Cross-clamp time			
All procedures (min)	179.0±61.3	183.2±56.7	0.70
Isolated procedures (min)	138.2±50.1	120.1±29.1	0.25

Values are presented as mean±standard deviation.

4) Statistical analysis

All data are expressed as means and standard deviations. Continuous variables were compared using the Student's t-test and categorical variables were compared using the chi-square test or Fisher's exact test. For all statistical analyses, SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used. A probability value of less than 0.05 was considered significant, accepting a confidence interval of 95%.

RESULTS

In the CS group, one patient with preoperative bacterial endocarditis and sepsis died of multiple organ failure on the second postoperative day. Most patients had a stable and uneventful course during the postoperative period. In the IS group, one patient died of ischemic brain damage on the 60th postoperative day. There were insignificant differences in aortic cross-clamp time and CPB time between the two groups (Table 3). In the IS group, two patients underwent AVR with the interrupted figure-eight suture technique, and one of the two showed a significant perivalvular leak in the first postoperative week and underwent reoperation during the same hospital stay. Another patient in the same group had a minor perivalvular leak, which was confirmed by echocardiography at one year postoperatively without significant physical or laboratory findings.

Table 4. Valve types and tranvalvular pressure gradients in the interrupted suture (n=47) and continuous suture (n=76) groups

Variable	Interrupted suture[a)]	Continuous suture	p-value
Bioprosthetic valve (n)	24	45	
Maximum pressure gradient (mmHg)	35.9±14.1	33.2±11.8	0.41
Mean pressure gradient (mmHg)	19.3±8.4	18.2±7.3	0.56
Mechanical valve (n)	22	31	
Maximum pressure gradient (mmHg)	29.2±15.2	25.2±11.0	0.27
Mean pressure gradient (mmHg)	15.8±7.7	14.0±6.1	0.35

Values are presented as mean±standard deviation.
[a)]One patient had no data due to early death after operation for endocarditis.

There were no differences in the mean or maximum transvalvular gradients of the bioprosthetic or mechanical valves between the two groups (Table 4), while the bioprosthetic valves showed a higher transvalvular gradient than mechanical valves regardless of the suture technique (mean pressure gradient, 18.5±7.7 mmHg in the bioprosthetic valves and 14.8±6.8 mmHg in the mechanical valves; p=0.06).

In the IS group, one patient undergoing isolated AVR with a pericardial valve had bacterial endocarditis combined with emboli in both lower extremities at postoperative year one. Another patient who had undergone AVR and concomitant tricuspid annuloplasty and a maze operation had *Candida parapsilosis* endocarditis at six months postoperatively. These two patients underwent replacement with a new bioprosthetic valve using the CS technique, and both recovered uneventfully.

In the CS group, there was no incidence of perivalvular leak or prosthetic endocarditis during a mean follow-up of 22.5±10.8 months. All of the patients recovered well without complications related to the suture technique.

Two patients with small annular dimensions in the IS group and three in the CS group underwent annular enlargement with the Nicks procedure for placing the correctly sized prosthesis (Table 5). In the CS group, two patients with aortic valve regurgitation underwent pericardial patch augmentation of the small noncoronary sinus.

Table 5. Enlargement of small aortic annuli and sinuses for aortic valve replacement

Variable	Interrupted suture	Continuous suture	p-value
Annular enlargement	3 (6.4)	2 (2.6)	0.37
Sinus enlargement	0 (0)	2 (2.6)	0.52

Values are presented as number (%).

DISCUSSION

One of the advantages of the CS technique compared with the IS technique is that the use of the thrombogenic material (no pledgets or braided suture knots) in valve replacement is not required. In our CS technique, the sutures were tied inside the aorta without pledgets, and the knots were fixed on the aortic sinus. This technique is also simpler and easier than previously reported techniques [1,2] in which the knots were placed buttressed by pledgets on the outside of three commissures. Such a suture technique may be more complex to perform.

In the IS group, most patients underwent AVR with horizontal mattress sutures buttressed by pledgets at the ventricular side. When pledgets are placed at the ventricular side, the annular margins may be exposed into the valve opening, which may disturb the leaflet movement of the mechanical valve or reduce the valve area in mechanical or bioprosthetic valves. With the CS technique, however, the annular tissue is buried in the CS line without the annular tissue being exposed to the prosthetic valve opening.

The suture plane in the aortic annulus is curvilinear, not horizontal, because it is the lowest at the nadir of each annulus and the highest at each commissure. With the IS technique, the suture line is compulsorily flattened by the hard sewing ring of the mechanical valve. The soft sewing ring of the bioprosthetic valve can be forced into an undesirable shape by the stronger curvilinear annulus. In the CS technique, however, the prosthesis is comfortably seated without regard to the curvilinear suture plane. Because each stitch in the CS technique is as high as the en bloc stitch, the prosthetic sewing ring is placed above the nadir of the annulus (supra-annular position) and below the commissure (infra-annular position). The flexible bioprosthetic sewing ring also

maintains its original shape, and the hard sewing ring of the mechanical valve does not affect the annular shape of the aortic root. One study [3] reported that the CS technique is advantageous in that a prosthesis one size larger than the largest size usable in the IS technique can be placed, because the aortic annulus is enlarged to some degree by the complete removal of the valve and the loosening of the contracted annulus. This results in better hemodynamic performance [4]. However, we did not observe this advantage in our study.

Prosthetic valve endocarditis is a rare but serious postoperative complication. With the CS technique, the risk of postoperative prosthetic endocarditis may be reduced without the use of pledgets or braided sutures. Some reports have noted that CS for AVR results in a shorter aortic cross-clamp time and a shorter bypass time [1,3]. However, we allowed for more time to make more stitches and thorough suture traction to ensure a secure suture line. We believe that a secure suture line is more important than a shorter operating time.

There has been some controversy regarding the increased incidence of perivalvular leak with the CS technique for AVR. Hjelms et al. [5] reported that the incidence of perivalvular leak was 8.8% in 80 patients undergoing AVR with the CS technique. Because the incidence of perivalvular leak was as high as 26% among patients with pure aortic insufficiency, they suggested that the CS technique was not suitable for patients with pure aortic insufficiency. In a recent study [3] with a 10-year follow-up after AVR, the incidence of moderate to severe paravalvular leak was 12% in the CS group, while the incidence was 0% in the IS group. However, Laks et al. [6] reported that the incidence of paravalvular leak with the CS technique was only 2.3%, which is comparable to that of the IS technique. Dhasmana et al. [7] reported that periprosthetic leakage without endocarditis was unrelated to the suture technique (interrupted versus continuous), but was related to suture size and annular calcification. They suggested the importance of meticulous annular decalcification and the use of a suture of smaller size, as in our experience. In a case report of significant paravalvular leakage seven years after AVR with the CS technique, the complication was caused by a broken suture [8]. The suture material used in most previous reports was 2/0 polypropylene with a thick needle, which may result in tissue injury during traction with a nerve hook to tighten the stitches. In the CS technique, special care should be taken to avoid trauma to the suture material during suturing. We suggest that a 17-mm, 1/2-circle needle is sufficient to make en-bloc annular stitches and that 3/0 polypropylene is strong enough to secure the suture line without tissue injury during traction of the stitches. In the CS group, no patients developed perivalvular leak during the follow-up period of 22.5±10.8 months (range, 3 to 40 months), but in the IS group, one patient had a significant perivalvular leak and one patient had a minor leak. One factor for the satisfactory achievement attained in this study may be the CS technique, in which deep stitches are made and which include the ventricular muscle (in the muscular part) or the adjacent strong fibrous tissue (in the aorto-fibrous continuity part) as well as the annulus. The stitch should also be deep in the subcommissural portion (interleaflet triangle). The height of each en-bloc stitch can ensure that the planes between the aortic annulus and the prosthetic sewing ring are well accommodated in the different levels. This mechanism of comfortably seating the valve is more important in aortic stenosis, which shows a hard curvilinear annulus due to the pathologic changes of marked thickening and contracture. Although the outcome of the CS technique for AVR in our cases has been satisfactory for about four years, long-term studies of the outcomes of this suture technique should be performed.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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